

# **PGF-SP CDR Part Four**

**Prepared by: Bionetics**  
**Date:09/10/2002**



# Agenda



## Part Four

- **System Summary and Project Status**

**11:00 - 11:30**

- **Weight and Center of Gravity**

- **Power Usage**

- **Lunch**

**11:30 - 12:00**

**12:30 - 2:30**

- **Risk Overview**

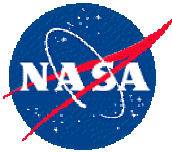
- **Reliability and Maintainability**

- **Hazards and Material Usage**

- **Flight Testing**



# Agenda



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## Part Three

- **System Summary and Project Status**  
**2:30 - 3:00**
  - **Project Status and Schedule**
- **Reviewers comments**  
**3:00 - 4:30**



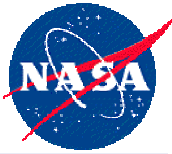
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# System Summary



# System Requirements Compliance

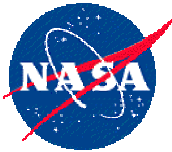
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- **Rolled up budgets**
  - **System performance**
  - **Weight and CG**
  - **Reliability**
- **Maintenance**
- **Replacement items and plan**
- **Diagnostic systems**
- **Material Usage List**
- **Single point failures**
- **Redundant systems**
- **GUI Review/Human Factors**



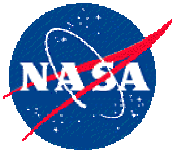
# System Weight



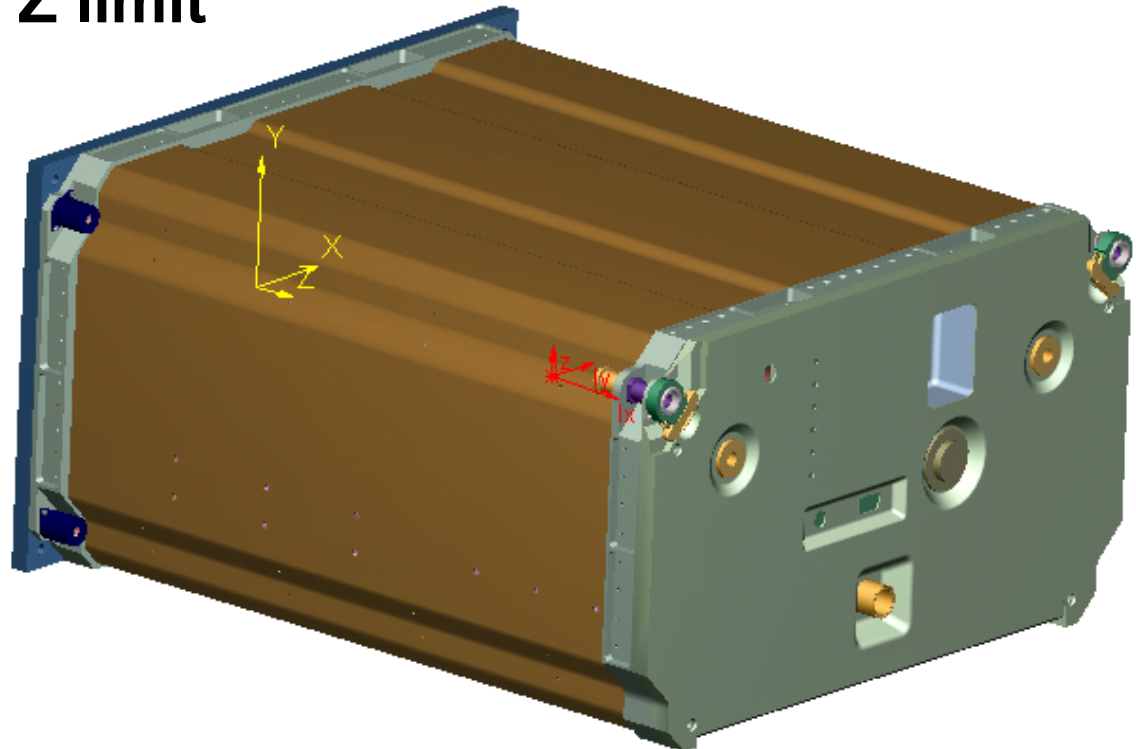
- **Current Weight estimate based on SolidWorks solid computer models**
  - **Includes two GFP imagers at 2.7 lbs.**
  - **Some items omitted**
    - **Some fasteners**
    - **Internal and MTL Cooling loop water**
    - **MTL cooling loop hoses, tees, connectors**
    - **Some insulation**
    - **Some small brackets and air baffles**
    - **Wires**
  - **Current Model Weight**
    - **60 lbs**
    - **Well within 69 lb limit**



# System Center of Gravity

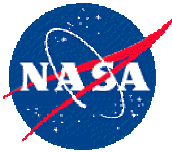


- **Current Center of Gravity estimate based on SolidWorks solid computer models**
  - **X, Y, Z = 0.095, 0.045, 9.713**
  - **Within 10.0" Z limit**





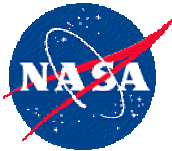
# Power Usage



- **Power Usage Estimate based on thermal analysis model for system**
- **Includes 1.15 Factor of Safety on TEC power for modeling uncertainty**
- **Includes 1.4 Factor of Safety on TEC power for dynamic variations**
- **Base on 35 cfm of cooling air on Middeck**
- **Based on 30°C (86°F) cabin/avionics air and EVA**
- **TAGES-2SD - 22°C and 80  $\mu\text{moles}/\text{m}^2/\text{sec}$**
- **RASTA - 23°C and 300  $\mu\text{moles}/\text{m}^2/\text{sec}$**
- **Based on 90% EMI filter efficiency**
- **Based on 85% DC/DC converter efficiency**



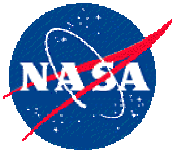
# Power Usage



| Device (both chambers)      | Power Usage (Watts) |       |
|-----------------------------|---------------------|-------|
|                             | TAGES-2SD           | RASTA |
| LED Banks                   | 15.6                | 57.2  |
| PGC Heaters                 | 4.8                 | 0     |
| PGC Fans and Sensors        | 4                   | 3.78  |
| Cooling Loop Pump           | 7                   | 7     |
| TECs                        | 40.6                | 36.2  |
| Locker Fans                 | 13.1                | 13.1  |
| Filtration Pumps and Valves | 1.8                 | 1.8   |
| Nutrient Pumps              | .8                  | .8    |
| Electronics                 | 12                  | 12    |
| Hand Held Interface         | 12                  | 12    |
| Power Converters/Filters    | 39.4                | 48.4  |
| Total Power Demand          | 151.1               | 193.1 |



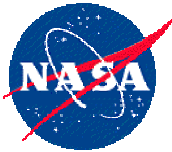
# Risk Overview



- **Overview of Procedure**
- **List of key risks**
- **Risks not retired and there current levels**
- **Mitigation Efforts**
- **Statement that our risk has been reduced to acceptable levels.**



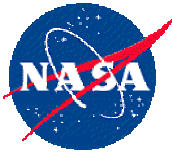
# Risk Management



- **Risk Management procedures adopted**
  - **Identify risks**
  - **Evaluate**
  - **Document corrective action plans**
  - **Track corrective action plans**
- **Improves hardware development process by preventing issues from becoming failures**
- **Process and techniques captured in**
  - **TAGES-2SD Risk Mgmt Plan**
- **Database used to capture and track individual risks**



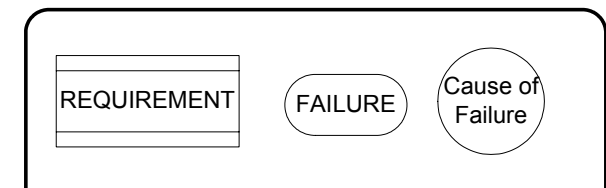
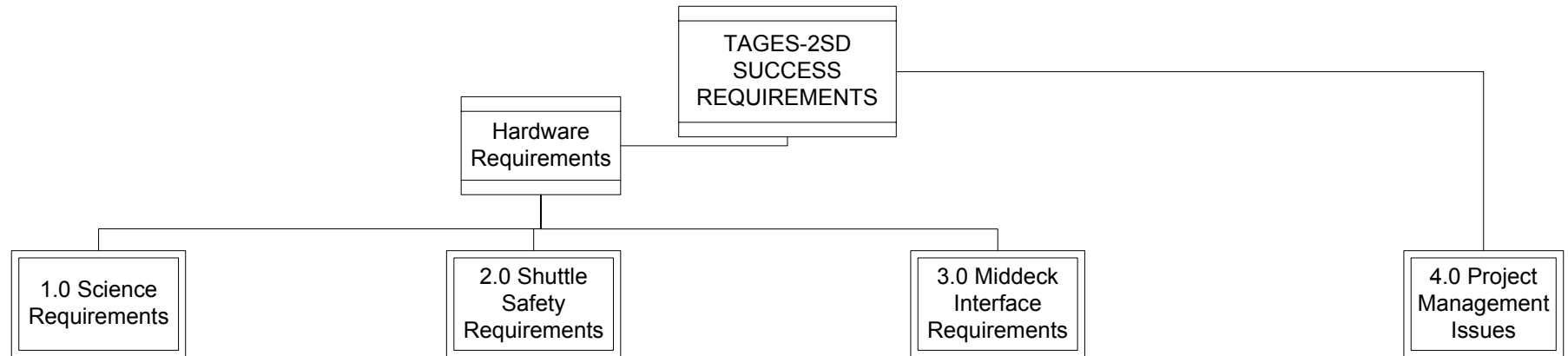
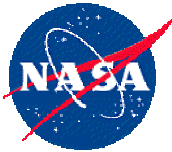
# Risk Management Procedure



- **Risks identified through formal and informal processes**
  - **Brainstorming**
  - **Preliminary Fault Tree Analysis**
  - **Daily activities**
- **Preliminary Fault Tree Analysis**
  - **Relates parent requirements to potential causes of failure**
  - **Systematically identifies risks using Fault Tree methods**
  - **Highly structured and thorough**

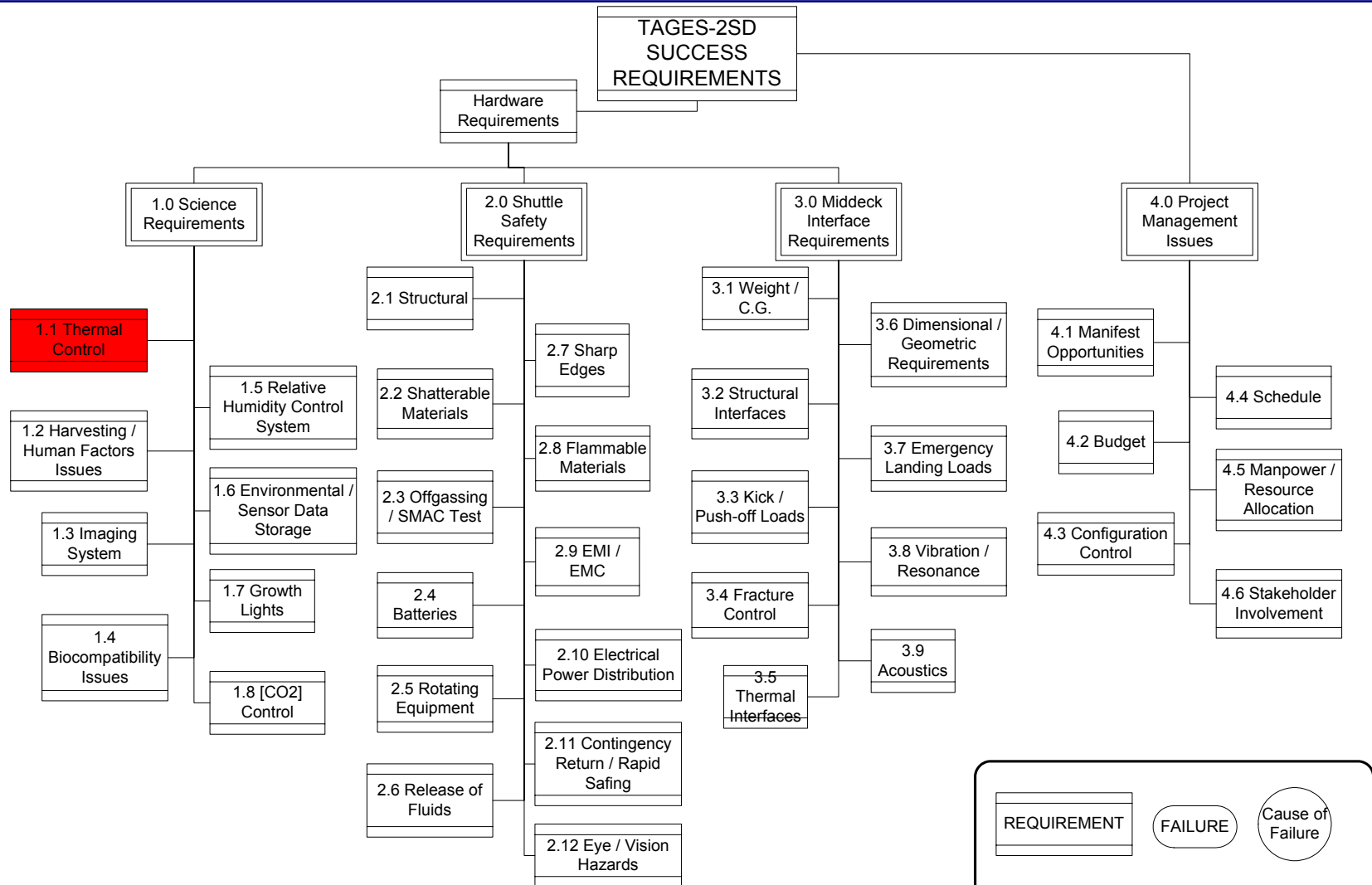


# Fault Tree Analysis - Top Level Requirements



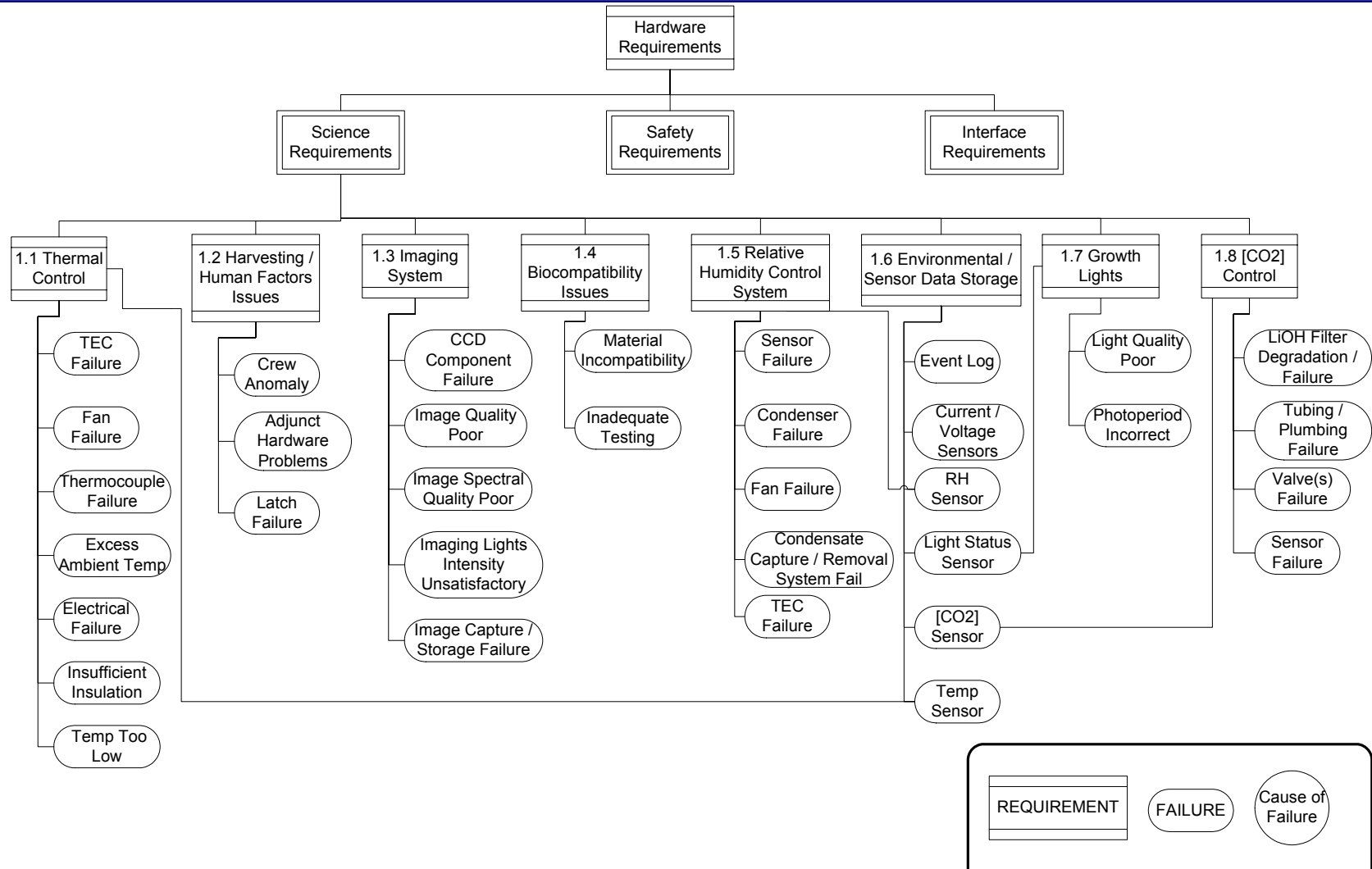


# Fault Tree Analysis - Requirements



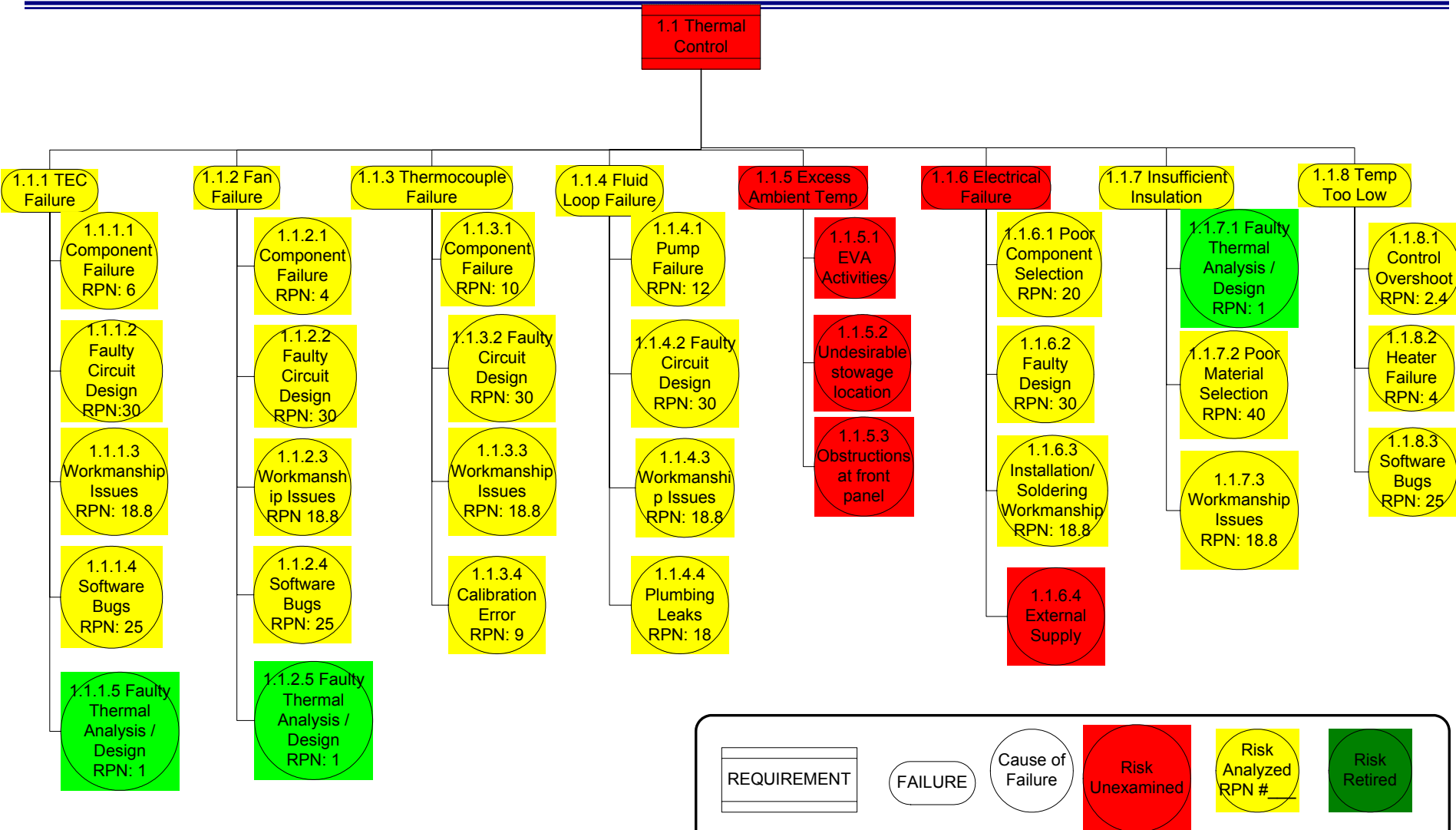
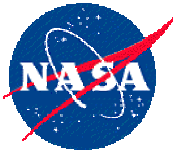


# Fault Tree Analysis - Failure Identification



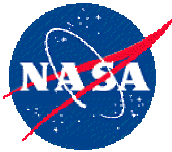


# Fault Tree Analysis - Failure Root Causes





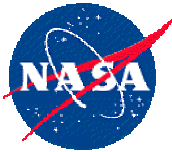
# Risk Tracking and Reduction



- Risks are evaluated based on there Risk Priority Number (RPN)
- $RPN = \text{Probability of Occurrence} \times (1 - \text{probability of detection}) \times \text{Magnitude of Impact} \times 100$
- Most risks should be reduced or retired by CDR
- No open risks with  $RPN > 10$
- No more than five risks between 5 and 10
- Many risks retired by CDR process
- Some additional work required to retire outstanding risks



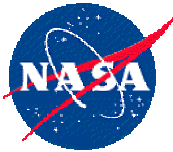
# Outstanding Risks



| Risk                           | Initial RPN | Corrective Action   | Status   | Retirement Event | Assignee   |
|--------------------------------|-------------|---|--|------------------|------------|
| Dehumidifier Development       | 300         | Protect electronics with conformal coating, test in KC135 | 1g evaluation successful, zero g test planned, Oct | KC-135 test      | M. Kelsch  |
| Changes in requirements        | 262.5       | Review requirements and performance at CDR                | CDR  | CDR              | M.Kelsch   |
| Limited manifest opportunities | 131.3       | Watch, design to improve manifest ability                 | No change  | Flight assigned  | K. Norwood |
| Schedule slips                 | 98.0        | Improve schedule accuracy                                 | Rescheduling for FY03                              | PVT              | K. Norwood |
| Late Design Changes            | 80.0        | Team Review post CDR changes                              | CDR  | PVT              | M. Kelsch  |



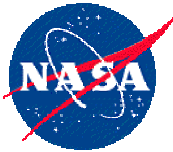
# Outstanding Risks



| <b>Risk</b>                          | <b>Initial RPN</b> | <b>Corrective Action</b>  | <b>Status</b>   | <b>Retirement Event</b> | <b>Assignee</b> |
|--------------------------------------|--------------------|---|---|-------------------------|-----------------|
| Water Containment                    | 70                 | Pressure check lines, add humidity sensor and screens to locker         | Screens and humidity sensors added to design                | CDR                     | M. Kelsch       |
| GFP Imager Development               | 70                 | Develop technical requirements from test                                | SVT completed feedback to design                            | GFP Imager CDR          | T. Murdoch      |
| Limited budget                       | 62.5               | Reduce prototype and breadboard efforts                                 | Developing FY03 Budget                                      | PVT                     | B. Wells        |
| Air filtration system fails on orbit | 60.0               | Mix specimens in chambers for redundancy, improve component reliability | GFP Imager in both chambers, additional cartridges provided | CDR                     | M. Kelsch       |



# Outstanding Risks



| Risk   | Initial RPN | Corrective Action   | Status  | Retirement Event | Assignee  |
|--|-------------|---|---|------------------|-----------|
| Software fails on orbit                        | 45          | Careful design and early testing                            | Architecture and base design complete                         | Mission          | D. Platt  |
| Poor insulation selection                      | 40          | Careful material review and analysis                        | Last-A-Foam selected and analyzed                             | CDR              | M. Kelsch |
| GFP imager fails on orbit                      | 30          | Redundant imagers   | Redundant imagers in design                                   | CDR              | M. Kelsch |
| No reliability and quality requirements in EIS | 20          | Add Reliability requirements and risk management to project | Reliability requirements and risk management added to project | CDR              | M. Kelsch |



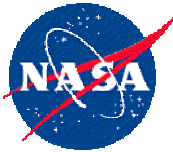
# Outstanding Risks



| Risk                                 | Initial RPN | Corrective Action                                       | Status   | Retirement Event | Assignee   |
|--------------------------------------|-------------|---|--|------------------|------------|
| Poor component selection             | 20.0        | Careful selection of proven parts, reliability analysis | Reliability Analysis complete on flight design | CDR              | T. Murdoch |
| Poor Workman-ship                    | 18.8        | Review WADs with technician/engineer                    | No work on WADs                                | WADs reviewed    | M. Kelsch  |
| Insufficient integration and testing | 18.0        | Draft integration and test plan by CDR                  | Test plan in CDR                               | CDR              | M. Kelsch  |
| Middeck/ISS interface differences    | 15          | Compare requirements, review differences at CDR         | Summary comparison in CDR package              | CDR              | M. Kelsch  |



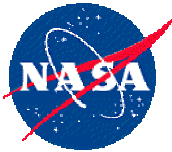
# Outstanding Risks



| Risk                                 | Initial RPN | Corrective Action  | Status  | Retirement Event          | Assignee   |
|--------------------------------------|-------------|--|---|---------------------------|------------|
| Temperature sensor failure           | 10          | Redundant temperature sensing in PGC                     | Redundant sensing not added   | Design changed            | T. Murdoch |
| Coolant Pump Failure                 | 10          | Determine reliability of pump, change if needed          | Reliability of pump is .98 for 25 day mission, added to limited life list | CDR                       | M. Kelsch  |
| Temperature sensor calibration error | 9.0         | Use digital devices, calibrate to high accuracy standard | Calibration plan required   | Calibration plan complete | M. Kelsch  |



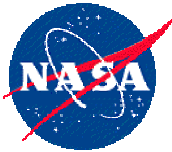
# Outstanding Risks



| Risk                                       | Initial RPN | Corrective Action  | Status  | Retirement Event                      | Assignee  |
|--|-------------|--|---|---------------------------------------|-----------|
| Inadequate thermal control                 | 7.5         | Redesign, analyze and test new design                            | Redesigned, analysis complete, more testing required          | Ground testing of breadboard complete | M. Kelsch |
| CDMS fails on orbit                        | 6.0         | Provide autonomous operation and manual capture of images        | Autonomous operation and manual imaging added to architecture | Software design completed             | D. Platt  |
| On orbit failure of locker circulation fan | 6.0         | Determine reliability of fan, make limited life item if required | Fan MTBF not determined, added to limited life items          | CDR                                   | M. Kelsch |



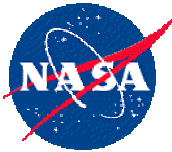
# Outstanding Risks



| Risk                                 | Initial RPN | Corrective Action                                       | Status   | Retirement Event | Assignee   |
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| Poor Workmanship                     | 18.8        | Review WADs with technician/engineer                    | No work on WADs                                | WADs reviewed    | M. Kelsch  |
| Insufficient integration and testing | 18.0        | Draft integration and test plan by CDR                  | Test plan in CDR                               | CDR              | M. Kelsch  |
| Middeck/ISS interface differences    | 15          | Compare requirements, review differences at CDR         | Summary comparison in CDR package              | CDR              | M. Kelsch  |



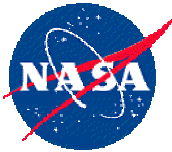
# Outstanding Risks



| Risk        | Initial RPN | Corrective Action                                       | Status   | Retirement Event | Assignee  |
|-------------|-------------|---|--|------------------|-----------|
| TEC Failure | 6.0         | Evaluate TEC reliability, add to limited life item list | Reliability of three TECs is .947, added to limited life items | CDR              | M. Kelsch |



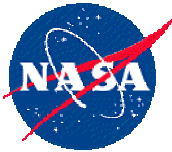
# Risk Summary



- **Most risks addressed by design reflected in CDR package**
- **Some risks still outstanding**
  - **Cooling and dehumidification system performance**
  - **Budget and schedule**
  - **Individual component reliability**
- **Additional work reflected in schedule**



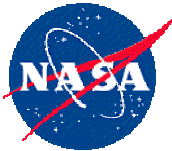
# Reliability Analysis



- **Reliability analysis was performed on individual boards to determine their ability to survive one mission**
  - 125 days total operation
- **Reliability was calculated using methods and values from MIL-HDBK-217F**
  - Conservative failure rate distribution
  - Conservative treatment of commercial electronics
- **EIS Reliability requirement of 90% after 120 day mission**
- **Risk management requires overall mission success to be guaranteed by 98.3% probability**
  - **Some science return**



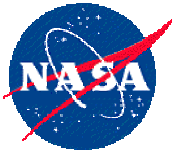
# Reliability



- **The reliability of each component was then used to determine the basic reliability of the PGF-SP subsystems**
- **The components used came from the flight design schematics**
- **Factors such as temperature, hours of use, part quality, environment, and stress were used to determine reliability**



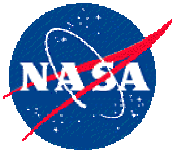
# Reliability Results



|                   | Basic Reliability at<br>3000 hours | Basic Mean Time<br>Between Failures (MTBF) |
|-------------------|------------------------------------|--|
| Power Module      | 96.72%                             | 89,986                                     |
| PGC Control Board | 98.30%                             | 174,966                                    |
| LLM               | 99.66%                             | 880,852                                    |
| CDMS              | 94.69%                             | 54,984                                     |



# Example Reliability Calculation



## PGC LED Illumination Board

| Part Number          |    | Fuse | Mosfet<br>ZNV4306A | Resistor | LED<br>APTD3216 |
|----------------------|----|------|--------------------|----------|-----------------|
| quantity             |    | 5    | 3                  | 6        | 434             |
| base failure rate    | Lb | 0.01 | 0.012              | 0.00098  | 0.00023         |
| temperature factor   | Pt | N/A  | 1.6                | N/A      | 2.1             |
| quality factor       | Pq | N/A  | 8                  | 15       | 8               |
| environmental factor | Pe | 0.9  | 0.5                | 0.5      | 0.5             |
| application factor   | Pa | N/A  | 0.7                | N/A      | N/A             |
| resistance factor    | Pr | N/A  | N/A                | 1        | N/A             |

|                                |    |       |         |         |          |
|--------------------------------|----|-------|---------|---------|----------|
| failures/10 <sup>6</sup> hours | Lp | 0.009 | 0.05376 | 0.00735 | 0.001932 |
|--------------------------------|----|-------|---------|---------|----------|

|             |         |          |          |          |          |
|-------------|---------|----------|----------|----------|----------|
| Reliability | R(3000) | 0.999973 | 0.999839 | 0.999978 | 0.999994 |
|-------------|---------|----------|----------|----------|----------|

|                                    |
|------------------------------------|
| Basic Reliability = .9966 = 99.66% |
|------------------------------------|

|              |             |           |             |             |
|--------------|-------------|-----------|-------------|-------------|
| MTTF (hours) | 111,111,111 | 8,680,556 | 136,054,422 | 517,598,344 |
| MTTF (years) | 12,684      | 991       | 15,531      | 59,087      |

Basic MTTF = 880852 hours



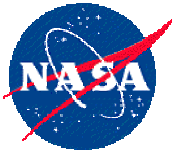
# Reliability and Maintainability



- **Reliability predictions will be used to evaluate designs and make changes to component selection or redundancy designs**
- **Reliability predictions will also be used to determine the rate of replacement for various PGF-SP components**
- **The PGF-SP is intended to operate for up to four (4) missions**
- **Some items may require replacement between missions to improve reliability**
- **More analysis is required with improved accuracy to prevent unnecessary maintenance**



# Limited Life Items



- **Preliminary list**
- **Items to be replaced after each mission**
  - **Locker Attachment Bolts**
  - **All Fans and impeller**
  - **Coolant Circulation Pump**
  - **Thermoelectric coolers**
  - **Power converters**



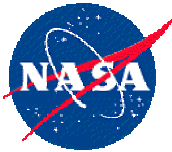
# PGF-SP Standard Hazards



- **Structural Failure**
  - **APML -**
    - **Structural analysis**
    - **Sine sweep and vibration testing**
  - **CCDL**
    - **Structural analysis**
    - **Sine sweep and vibration testing**
- **Sharp Edges**
  - **All accessible equipment**
    - **Design to requirements**
    - **Post assembly inspection**



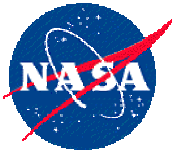
# PGF-SP Standard Hazards



- **Electrical Shock**
  - **28 volt supply and 24/12/4 volt internal**
    - No exposed bare contacts
    - Insulated wire
- **Batteries**
  - **Clock battery**
    - Already approved for use on Magnetic Field Apparatus (MFA) equipment
- **Touch Temperature**
  - **Thermal Control System**
    - Analyzed for maximum operating temperature
    - Temperature sensors and software cutoff on heat sources



# PGF-SP Standard Hazards



- **Touch Temperature (continued)**
  - **Electronics/Power Converters**
    - Contained in electronics housing
- **Rapid Safing**
  - **Tray Insert Assembly**
    - Easy drawer slide operation
  - **Root Tray Modules**
    - Easy Installation
- **Radiation-nonionizing**
  - **No sources of radiation**



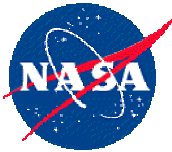
# PGF-SP Standard Hazards



- **Rotating Equipment**
  - **Locker Cooling Fans and PGC Circulation Fans**
    - Finger guards to be added
    - Thread locking inserts on fasteners
- **Mating and Demating of Power Connectors**
  - **Main power connector**
    - Designed in accordance with Middeck and EXPRESS Rack IDDs



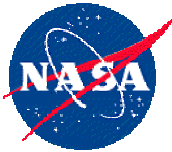
# PGF-SP Standard Hazards



- **Flammability and Off gassing of materials**
  - **Significant plastic construction including**
    - Polycarbonate
    - Polyurethane foam (last-a-foam)
    - PEEK
    - Delrin
    - 966 acrylic adhesive
  - **Materials selected which are UL94-V0 rated**
  - **Materials selected which are approved or similar to approved materials**



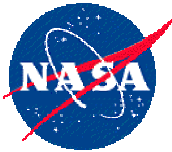
# PGF-SP Unique Hazards



- **Release of Hazardous Materials**
  - **Lithium Hydroxide (120 grams in PGF-SP)**
  - **Potassium Permanganate (8 grams in PGF-SP)**
  - **Stowed replacement cartridges**
  - **Double filter design to prevent escape**
    - **Stainless steel mesh**
    - **Filter paper**
- **Release of Non-hazardous Materials**
  - **Coolant Water (deionized water)**
    - **60 ml per loop, two loops**
    - **Pressure tested lines and fitting**



# PGF-SP Unique Hazards



- **Release of Non-hazardous Materials (continued)**
  - **Recovered condensate**
    - Pressure tested lines and fittings
    - Relief to condensate collection unit or Nutrient reservoir
    - 60 ml reservoir
    - Double contained reservoir
  - **Nutrient Solution**
    - Pressure tested lines and fittings
    - Relief to root tray module
    - 100 ml reservoir
    - Double contained reservoir



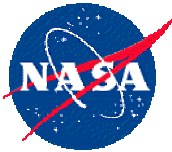
# PGF-SP Unique Hazards



- **Release of Non-hazardous Materials (continued)**
  - **Moderate Temperature Water Loop Coolant**
    - **Pressure tested lines and fittings**
- **Eye Damage**
  - **High intensity LEDs**
    - **Prolonged close range viewing may cause damage**
  - **Interlock on front door to place system in stand-by mode (lights off) when locker opened**
  - **Crew training to inform them of hazard**
  - **Label on root trays noting hazard**



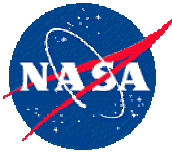
# Critical Item List



- **Structural Equipment**
  - **APML**
  - **CCDL**
- **Pressure Vessels and Lines**
  - **All water lines and fittings**
  - **Nutrient Reservoir**
  - **Priming Reservoir**



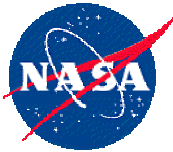
# Critical Item List



- **Safety Limits/Sensors**
  - **Main breaker**
  - **Main outlet thermostat**
  - **Inlet and outlet temperature sensors**
  - **Heat sink temperature sensors**
  - **Front door interrupt switch**



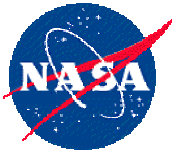
# Material Usage - Metals



| Item                                   | Material                | Construction     |
|--|-------------------------|------------------|
| APML (Locker)                          | 7075-T73, 7050-T73      | Chromate Coating |
| Locker Paint                           | Per EXPRESS Rack<br>IDD |                  |
| Locker Latches, Tray<br>Latches        | 15-5PH H1025            | Passivated       |
| Electronics Housings                   | 6061-T6                 | Chromate Coating |
| Heat Sinks                             | 6061-T6                 | Chromate Coating |
| Support Brackets,<br>Cowlings, Baffles | 6061-T6                 | Chromate Coating |



# Material Usage - Non-Metals



| Item   | Material                              | UL94 Rating    |
|--|---------------------------------------|----------------|
| <b>PGC Housing structural elements, Reservoir housings</b> | <b>Polycarbonate 900 series LEXAN</b> | <b>V0</b>      |
| <b>PGC Face sheets and LED Window</b>                      | <b>Polycarbonate FR-60 LEXAN</b>      | <b>V0</b>      |
| <b>Face Sheet Adhesive</b>                                 | <b>3M 966 acrylic film transfer</b>   | <b>Unknown</b> |
| <b>Dehumidifier Sponge</b>                                 | <b>Polyvinyl alcohol</b>              | <b>Unknown</b> |
| <b>PGC Insulation Foam</b>                                 | <b>Last-A-Foam 6703</b>               | <b>Unknown</b> |
| <b>PGC internal paint</b>                                  | <b>MIL-PRF-85285C</b>                 | <b>Unknown</b> |



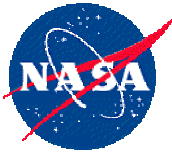
# Material Usage - Non-Metals



| Item  | Material                          | UL94 Rating |
|---|-----------------------------------|-------------|
| Electronics Support Bracket, other support pieces | Fiberglass G10/FR4                | V0          |
| Carbon Dioxide and VOC Scrubber Bodies            | Polycarbonate<br>900 series LEXAN | V0          |
| Low pressure water lines                          | Platinum Cured<br>Silicone Tubing | Unknown     |
| Filtration Air Lines                              | TYGON Food and Beverage           | Unknown     |
| Small Diameter Water Lines                        | Lee MINSTAC Tubing                | Unknown     |



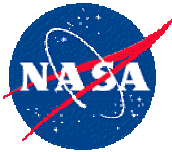
# Material Usage - Non-Metals



| Item                                 | Material                      | UL94 Rating |
|--------------------------------------|-------------------------------|-------------|
| Foam insulation, electronics housing | Silicone Foam (TBD)           | V0          |
| Water and Air manifolds              | PEEK                          | V0          |
| Fan Housings and blades              | Black Plastic                 | V0          |
| Motorized Impeller                   | Unknown                       | Unknown     |
| Wiring                               | Copper with Teflon insulation | V0          |



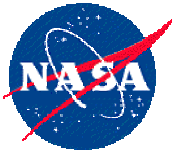
# Flight Hardware Testing



- **Structural Testing**
  - **Middeck random vibration/sine sweep**
- **Environmental Testing**
  - **Functional and performance testing**
  - **Safe Operation and safety limits**
- **Electrical**
  - **EMI/EMC**
  - **Shuttle and ISS interface simulation**
  - **Voltage range**
  - **Grounding and isolation**



# Flight Hardware Testing



- **Software Function**
  - **Fault tolerance**
  - **Data storage/retrieval**
- **Inspection**
  - **Overall Dimensions**
  - **Weight and Center of Gravity**
  - **Operator Interfaces**
  - **Sharp edges**
- **Science Verification**
  - **Payload Verification Test**



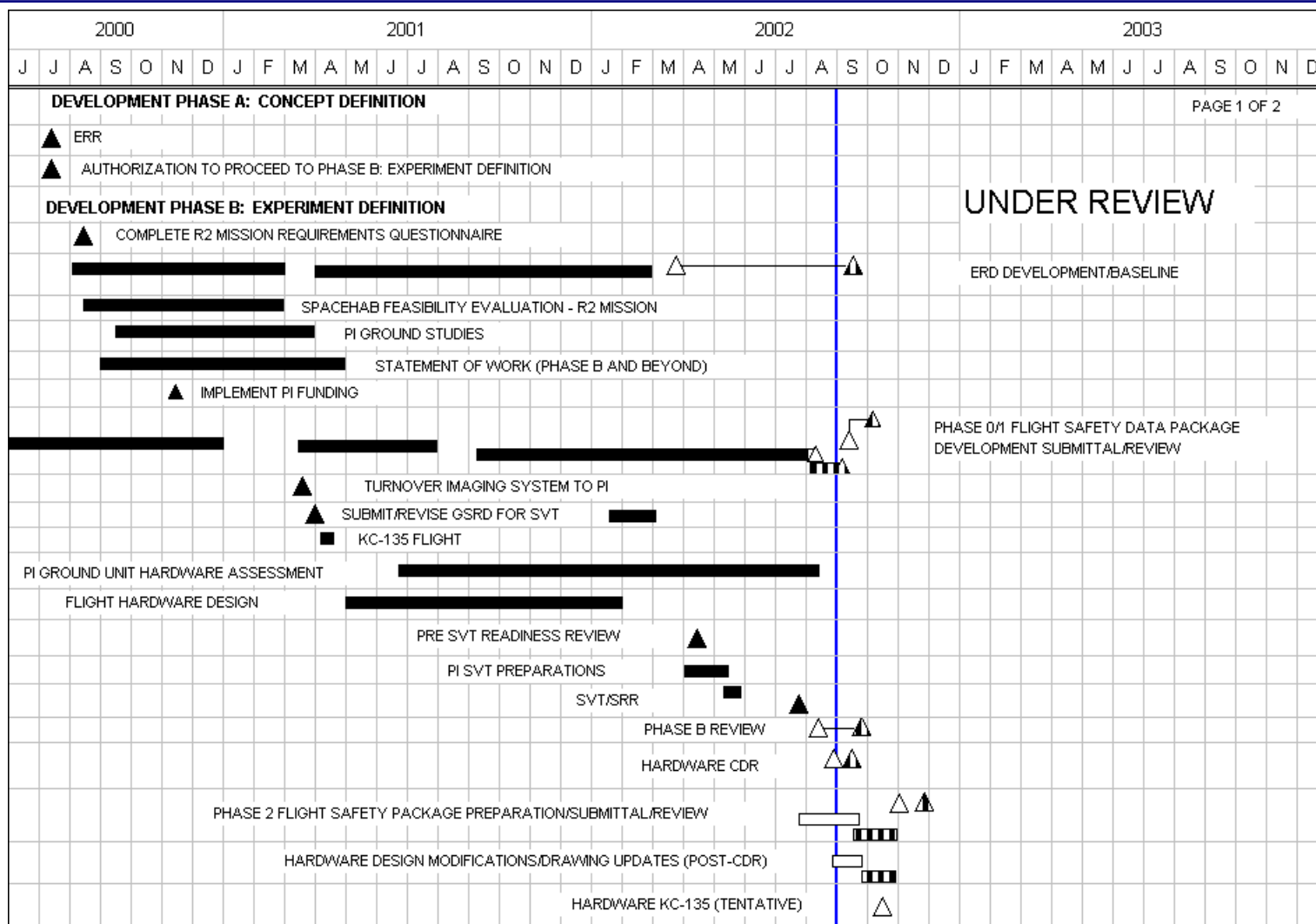
# Project Status



- **ERDs and EIS in review**
- **Prototype fully tested**
- **Thermal Control Breadboard (new cooling and dehumidification design) completed and partially tested**
- **Science Readiness Review Completed**
- **Flight Design of Single Locker System 90%Complete**
- **Assembly Drawings Started**

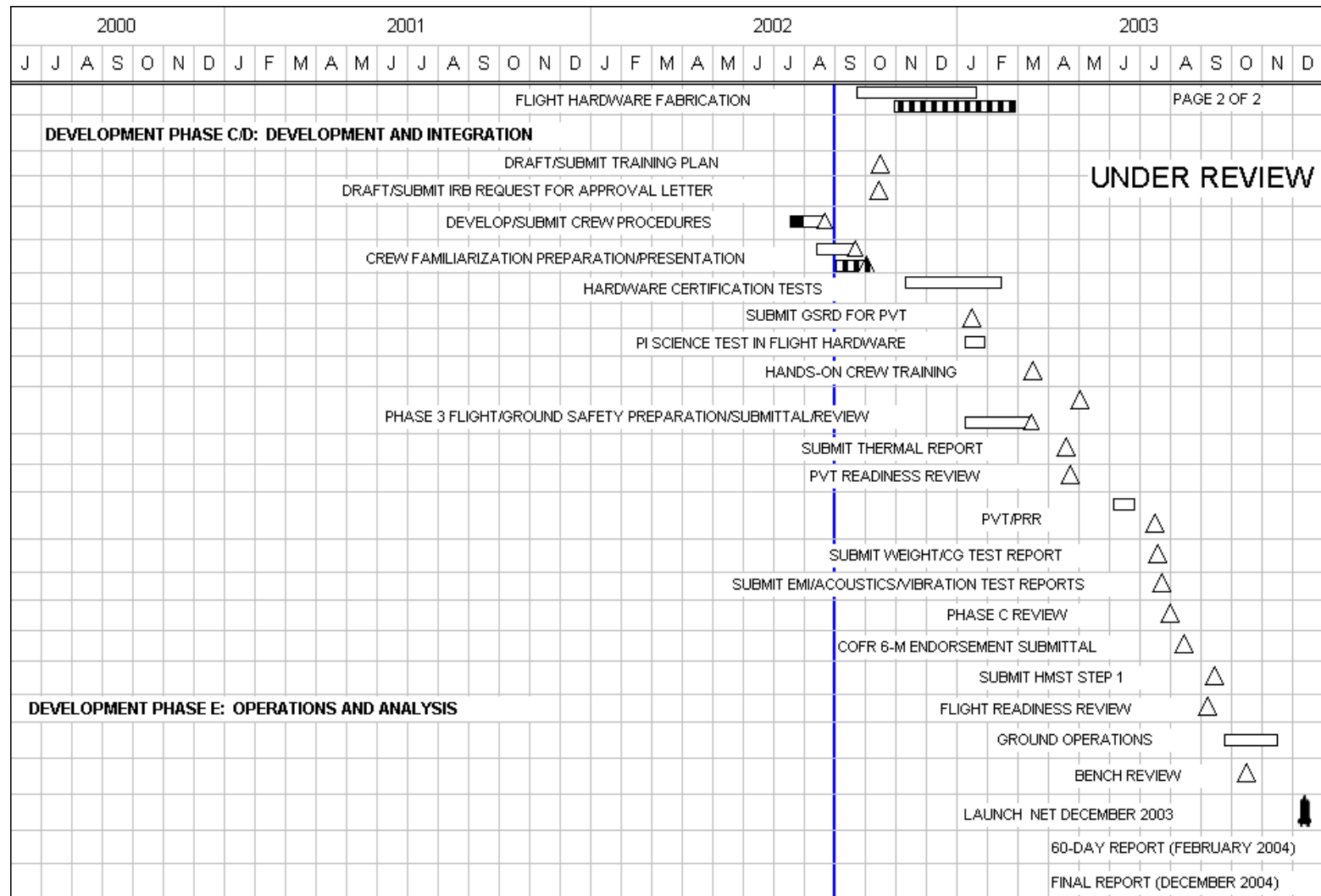
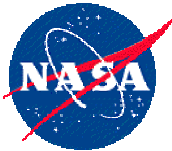


# Project Schedule



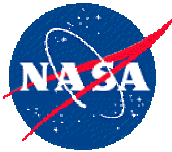


# Project Schedule





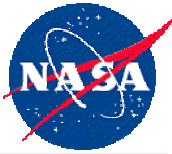
# CDR Summary



- **Open Issues**
  - **Some risk reduction efforts still required**
    - Thermal control and dehumidification
    - Reliability
  - **Locker modifications and structural analysis required**
  - **Design of double locker configuration required**
- **Ready to complete testing and analysis and begin flight fabrication**



# Review of Action Items



- **Review of review action items**